

U.S. Mines Bureau

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FRANKLIN K. LANE, SECRETARY

BUREAU OF MINES

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WAR MINERALS
NITROGEN FIXATION
AND SODIUM CYANIDE

Advance Chapter from Bulletin 178
War Work of the Bureau of Mines

BY

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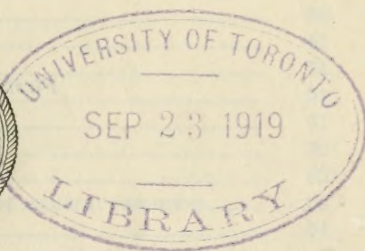
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ENGINEERING

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WAR MINERALS, NITROGEN FIXATION, AND SODIUM CYANIDE.

WAR MINERALS INVESTIGATIONS.

GENERAL STATEMENT.

The term war minerals has been applied to those ores and minerals that were largely imported before the war. Among the more important of these are manganese, essential for making high-grade steel for munitions and industrial use; graphite, for making crucibles; tin, for plating utensils and for bearing-metal; mercury, used as fulminate to explode shells; potash, for making fertilizer and explosives; tungsten and molybdenum, for high-speed tool steel; antimony, for hardening bullet lead; chromite, for tool steel, for tanning leather, and as a refractory lining in furnaces; magnesite, for refractory linings; mica, as insulating material; platinum, for the manufacture of sulphuric acid and for electrical apparatus.

When the United States entered the war it was clear that every ship would be needed and that the number available for importing minerals would be small. Hence a quick and thorough survey of domestic resources was necessary.

Throughout the war the scope and volume of the war-minerals work increased until it covered practically every mineral that was known to be or was liable to be in short supply.

BEGINNING OF THE WORK.

Before this country entered the war, the Bureau of Mines on its own initiative or in cooperation with other Government organizations, had already begun investigations of the more important minerals or mineral products. Among them were nitric acid, sulphuric acid, and potash. In 1916, as related elsewhere (p. 55), the chief chemist of the bureau inspected nitrogen fixation plants in Europe, as the accredited representative of the War Department, and after his return devised a highly efficient method of manufacturing nitric acid, which was used in the development of a Government plant. When the blockade cut off the importation of potash from Germany, the Bureau of Mines in cooperation with the United States Geological Survey, Bureau of Soils, and other Government agencies began an investigation of sources of potash and methods of manufacture. In cooperation with the War Department, a study of the sulphuric acid

situation was begun about the same time that of nitric acid was taken up.

After the declaration of war the bureau took a leading part in investigations aimed to prevent deficiencies in the supplies of needed minerals. The director of the bureau served as a member of the military committee of the National Research Council and of the various committees on mineral products under the Council of National Defense. Representatives of the bureau served on and took an active part in the work of the War Minerals Committee, established in July, 1917, for studying the minerals situation, and of the Joint Information Board on Minerals and Derivatives. The bureau has had charge of the extensive investigations of war minerals conducted under the \$150,000 emergency fund appropriated in March, 1918.

The Bureau of Mines has endeavored to aid producers of war minerals by taking up questions of priority, transportation, fuel, and equipment, construction of highways and roads, labor supply, and the study of the best mining methods and concentrating practice for the development of these new materials. The results of the bureau's investigations have been condensed into summarized reports for the War Industries Board, the United States Shipping Board, and other Government establishments.

WAR MINERALS COMMITTEE.

The War Minerals Committee, established in July, 1917, was composed of William Young Westervelt, representing the American Institute of Mining Engineers and the Mining and Metallurgical Society of America; W. O. Hotchkiss, representing the Association of State Geologists; David White, of the United States Geological Survey; and A. G. White, of the Bureau of Mines; later H. S. Mudd acted as assistant secretary. This committee aided in establishing cooperation between the bureau and the various agencies interested in the development of minerals; it also assisted in outlining investigations and in obtaining the best available men for special work.

JOINT INFORMATION BOARD.

The Joint Information Board on Minerals and Derivatives was organized to act as a clearing house for information to all of the Government departments interested in mineral problems. H. S. Mudd acted as the representative of the Bureau of Mines on this board.

SPECIAL APPROPRIATION.

In the latter part of March, 1918, Congress in the urgent deficiency bill appropriated \$150,000, to be expended under the Bureau of Mines, to extend and continue investigations relating to minerals of

military importance. The general purpose of this work is indicated by the heading under which the appropriation was made:

War materials investigation.—For inquiries and scientific and technologic investigations concerning the mining, preparation, treatment, and utilization of ores and other mineral substances which are particularly needed for carrying on the war, in connection with military and manufacturing purposes, and which have heretofore been largely imported, with a view to developing domestic sources of supply and substitutes for such ores and mineral products as are particularly needed, and conserving resources through the prevention of waste in the mining, quarrying, metallurgical, and other mineral industries.

This appropriation permitted organization and work on a much more extensive scale, although a large amount of war minerals work had already been undertaken by the Bureau of Mines.

MINERALS ADMINISTRATION ACT.

The so-called war minerals bill was submitted to Congress in December, 1917. Originally limited to a few special minerals, the bill was later broadened to include all minerals, and finally was again restricted to a group consisting principally of minor and rare metals and minerals. The bill was passed by the House on April 30, and in modified form by the Senate on September 11. It was approved by the President on October 5, 1918.

By Executive order of November 11, 1918, the administration of the act was delegated to the Secretary of the Interior. On that date the armistice ended hostilities. As the act primarily provided for insuring production for war purposes, it was not a reconstruction measure and further legislation was required for that purpose.

An amendment to the minerals control act, authorizing the Secretary of the Interior to examine claims and pay off financial losses of the producers of certain war minerals, where it could be shown that such production had taken place as a result of Government action, was attached to the Dent military bill, which was signed by the President on March 3, 1919. The measure authorizes investigation of net losses incurred by producers of manganese, chrome, pyrite, and tungsten. The maximum amount to be expended under the provision is limited to \$8,500,000. A commission of three members, to be known as the War Minerals Relief Commission, will review the claims and make the awards. The Secretary of the Interior has authorized the Director of the Bureau of Mines to conduct the field engineering and accounting investigations, also the office routine and administrative work for the commission. The members of the commission are J. F. Shafroth, M. D. Foster, and P. N. Moore.

PERSONNEL OF WAR MINERALS INVESTIGATIONS.

At the close of the war the personnel of the war minerals investigations included some 90 mining engineers, metallurgists, and chem-

ists. Of these about two-thirds were engaged in the staff and field work of the longer investigations, the rest were consulting engineers working on special problems. The war minerals investigations were in charge of J. E. Spurr as chief executive. At first they were temporarily under the direction of D. A. Lyon, supervisor of the bureau's mining experiment stations.

The general staff consisted of H. H. Porter, in charge of priority matters; F. W. Paine, in charge of shipping problems; H. S. Mudd, representative on the Joint Information Board, and matters relating to highways and roads; A. G. White, matters of organization and planning, and excess-profits taxes; R. R. Hornor, mining methods; J. H. Mackenzie, mining costs, and ore markets; H. C. Morris, matters relating to work of the Capital Issues Committee; J. E. Orchard, political and commercial control of minerals; Oliver Bowles, informational, and nonmetallic minerals; C. T. Robertson, files and editing of manuscripts. In addition to this general staff were the engineers in charge of the researches on the different minerals.

The work of the war minerals investigations has been closely associated with the work done at the mining experiment stations of the bureau under the direction of the division chiefs of the bureau and the supervisor of the experiment stations. The Minneapolis, Minn., station worked entirely on problems related to manganese ores; the Columbus, Ohio, station took up special investigations of domestic clays, graphite, and refractories; the Urbana, Ill., station worked at the recovery and use of pyrite from coal mines; the Golden, Colo., station studied the recovery of potash, tungsten, and other rare metals; the Tucson, Ariz., station made field investigations of manganese ores; the Salt Lake City, Utah, station investigated graphite milling; the Berkeley, Calif., station gave attention to the concentration and recovery of quicksilver and sulphur; the Seattle, Wash., station studied concentration of chrome and tin.

MANGANESE.

Manganese was in some respects the most important of the war minerals. The United States requirements for 1918 were estimated to be 798,000 tons of high-grade ore. Because of the need in the steel industry, little reduction of consumption was feasible; hence the problem confronting the Bureau of Mines was to endeavor to stimulate domestic production so as to release bottoms that would otherwise be used in importing some 650,000 tons of manganese ore.

Because of the importance of the investigations a large number of engineers were assigned to them. Some engineers investigated all the known manganese deposits in this country as well as deposits in Canada and in Cuba, other engineers assisted mine operators in

utilizing the best mining and concentrating methods and aided the small producers, others endeavored to develop improved methods of milling and concentrating, others devoted their attention to metallurgical practice at blast furnaces smelting manganese alloys.

As a result of the demand for manganese and the work done by the Government the domestic production of manganese in 1918 was about 294,497 tons, as compared with a production in 1913, before the war, of 4,048 tons.

Practically all the work of the Minneapolis station in 1918 was on manganese, especially the concentration and beneficiation of low-grade ores. Edmund Newton, superintendent of the station, was charged with the preliminary organization of all the manganese investigations. H. C. Morris organized the field investigation in cooperation with Mr. Newton. In July, 1918, the work on manganese as related to the war minerals investigations was placed in charge of C. M. Weld.

FIELD EXAMINATION OF MINING AND MILLING METHODS.

W. C. Phalen made a preliminary investigation of the manganese mines of the country. In the fall of 1917, through cooperation with the War Minerals Committee and the American Institute of Mining Engineers, P. N. Moore, A. H. Rogers, R. H. Richards, and F. Lynwood Garrison, mining engineers, spent several weeks in studying mining and washing methods in Virginia. W. R. Crane investigated the Georgia deposits in cooperation with the State Geological Survey; E. R. Eaton studied the improvement of mining and beneficiation methods in the South; and E. G. Spilsbury, a consulting engineer of the bureau, examined one of the new Virginia districts. C. E. Van Barneveld, superintendent of the Tucson station, investigated many of the western deposits. G. D. Louderbach examined the California deposits in cooperation with the United States Geological Survey and with State organizations. G. H. Clevenger studied the recovery of manganese from the ores of the Cripple Creek district. T. M. Bains and G. E. Ingersoll examined the manganimiferous deposits of the Cuyuna and other ranges in Minnesota.

In April and May, 1918, Albert Burch, for the Bureau of Mines, and E. T. Burchard, for the Geological Survey, investigated the manganese resources of Cuba.

BLAST-FURNACE PRACTICE.

Early in 1918 H. D. Hibbard and J. E. Johnson, consulting engineers, and Edmund Newton, superintendent of the Minneapolis station, investigated metallurgical practice at steel plants, using low-manganese alloys produced largely from domestic ores.

USE OF MANGANESE ALLOYS IN OPEN-HEARTH STEEL PRACTICE.

A study of the use of manganese alloys in open-hearth steel practice was undertaken to determine the most suitable means of utilizing domestic manganese and the extent to which low-grade alloys could be substituted for high-grade alloys without impairing the steel produced either as to quantity or quality. The principal furnaces were visited and the reactions taking place in the furnace studied, and samples of metal and slag taken. A report on the results of the work was prepared for publication. This work was conducted by S. L. Hoyt, F. B. Foley, and R. L. Dowdell.

PRODUCTION OF FERRO-MANGANESE AND SPIEGELEISEN.

In order to collect and prepare data on the production of ferro-manganese and of spiegeleisen in blast furnaces, 18 furnaces, including all furnaces in blast on manganese alloys, were visited. Furnace records, charge sheets, and analyses over long periods were compared, and various factors, such as blast temperature, composition of alloy and of slag, etc., were studied during representative periods of furnace operation. A report was prepared on the results of this work, which was conducted by P. H. Royster.

ELECTRIC SMELTING OF SILICO-MANGANESE.

As silico-manganese had been used to some extent by steel makers and as an increase in its use would have helped to relieve the manganese situation, laboratory experiments on the electric smelting of silico-manganese were made. This work was done by H. W. Gillett, alloy chemist of the bureau, who prepared a report on the experiments and the results obtained.

ORE-DRESSING TESTS.

Samples of ore from different States were tested at the Minneapolis station in the effort to devise improved methods of dressing and to assist operators in preparing their ores for market. These tests were conducted by J. W. Norton and H. H. Wade.

TESTS OF JONES AND BOURCOUD PROCESSES.

Two new processes for utilizing low-grade and complex ores were examined at the Minneapolis station. The Jones process for the direct reduction of manganiferous iron ores was shown to be metallurgically feasible. A similar series of experiments on the Bourcoud process was in progress on March 1, 1919. These tests were made under the direction of Peter Christianson, consulting engineer.

When all the manganese work is completed the various reports on manganese and manganese alloys will be assembled and published as a bulletin of the bureau.

RECONSTRUCTION WORK.

After the armistice was signed the demand for domestic ores fell. The Bureau of Mines at once instructed its field men to discourage further expansion of the manganese mining, and to advise producers as to the most efficient methods, so that they might have a better chance of meeting the competition of imported ores.

COLLECTION OF STATISTICS ON CONSUMPTION.

From the results of information obtained in the field and through monthly reports from consumers of manganese ore and of ferro-alloys, the available supplies of ore were ascertained. A careful study of the requirements of furnaces was also made and valuable supplies were conserved. This statistical work was in charge of W. C. Phalen and W. R. Crane.

CHROMITE AND CHROMIUM.

Estimates made soon after the bureau's war investigations began placed the country's requirements for 1918 at 130,000 tons of chromite. In 1917 the imports from Rhodesia and New Caledonia amounted to some 43,000 tons. As there seemed little probability that production from domestic sources could be increased enough, effort was made to stimulate production in other countries of America as well as in the United States. The domestic output in 1918, however, was about 64,590 long tons of chromite (50 per cent Cr_2O_3), or 14,590 tons more than was anticipated. Thus the bureau's investigations demonstrated that the chrome resources of the United States would yield at war prices a large production for some time. The chromite investigations were under the general charge of J. H. Mackenzie and J. E. McGuire.

Efforts were also made to devise substitutes for chromite used in refractories and to demonstrate the possibility of decreasing the amount of chromium salts used for tanning leather and for other purposes. A special study of substitutes for chrome brick was started at the Columbus experiment station under R. T. Stull, superintendent. H. D. Hibbard has submitted a report on the use of chromite as a refractory.

As the chromium-bearing iron deposits in Cuba were reported to promise a source of chrome, Albert Burch of the bureau, accompanied by E. F. Burchard of the United States Geological Survey, visited them and subsequently prepared a report on the probable extent of the principal deposits and the feasibility of developing them.

Deposits in Newfoundland, in North Carolina, in Pennsylvania, and in the Western States were also investigated. These investiga-

tions were made by Albert Burch, assisted by field engineers J. E. McGuire, E. G. Hill, and F. H. Probert.

Concentrating tests of low-grade chrome ore were made at the bureau's experiment stations at Berkeley, Cal., and at Seattle, Wash.

A survey of the ferrochrome situation was made by R. M. Keeney.

TIN.

The United States uses annually about 70,000 tons of tin, but produces only 100 tons, chiefly from Alaska. As a large part of the tin consumed was used as tin plate for food containers and these were of vital importance to the Army and Navy, every effort was made to insure an adequate supply.

Domestic deposits of tin ore were investigated and partly as a result of such investigations a Virginia deposit was commandeered by the War Department and turned over to a Boston company to develop. R. R. Hornor examined the tin deposits in the Black Hills of South Dakota and the samples he collected were subjected to milling tests at the Seattle experiment station. Thomas Leggett investigated the tin area of North and South Carolina.

The use of substitutes for tin and the reclamation of used tin were investigated at the Seattle station.

Encouragement of the smelting in this country of Bolivian tin ore so as to reduce the need for importing Straits tin also seemed desirable. A commission headed by Charles Janin, of the Bureau of Mines, and including Howland Bancroft, of the bureau, investigated the Bolivian tin situation. H. Foster Bain, assistant director of the bureau, was in charge of the work on tin.

PYRITE.

Pyrite is used in making sulphuric acid, which is indispensable in the manufacture of explosives. After this country entered the war practically every known pyrite deposit of importance in the United States was investigated by representatives of the Bureau of Mines. These investigations have demonstrated that there are large pyrite deposits which can be developed to meet any shortage that may arise. Valuable assistance was rendered to new mines in the matter of priorities, labor supply, and improved methods of mining.

The recovery of copper from pyrite cinder was studied by D. E. Fogg and tests were made to determine whether the cinder could be used for making low-phosphorous iron.

A complete survey was made of the producing pyrite mines in Colorado and the Eastern States. C. E. Julihn investigated deposits in the Southern States; R. R. Hornor did field work in Virginia, New York, Wisconsin, Missouri, and Colorado. In cooperation with the

State geological surveys of Pennsylvania, West Virginia, Ohio, Kentucky, Tennessee, Indiana, Illinois, Michigan, Missouri, and Iowa; E. A. Holbrook investigated the possible recovery of pyrite at coal mines. The results of work at the Urbana experiment station indicate that much pyrite may be obtained from this source. The pyrrhotite deposits at Pulaski, Va., have been thoroughly examined. A method for concentrating pyrrhotite by electrostatic concentration was developed at the Golden station.

The work on pyrite was under the supervision of H. A. Buehler.

SULPHUR.

In October, 1917, the possible output of the two chief commercial deposits of native sulphur were examined by J. Parke Channing, J. W. Malcolmson, and A. B. W. Hodges, consulting engineers of the Bureau of Mines, W. O. Hotchkiss, representing the War Minerals Committee, and P. S. Smith, representing the United States Geological Survey. This investigation was made to determine whether the sulphur output could meet the war requirements.

In 1918 C. O. Lindberg, of the Bureau of Mines, made a thorough examination of western sulphur deposits, with a view to determining the possibilities of their development commercially or to meet an emergency. Concentration tests of samples from the deposits were made by J. M. Hyde at the Berkeley mining experiment station.

SULPHURIC ACID.

A. E. Wells, superintendent of the Salt Lake City mining experiment station, was put in charge of the sulphuric acid investigations; he cooperated with the War Industries Board and with the Chemical Alliance. A statement was prepared for the Railroad Administration and for the Shipping Board on the transportation of brimstone to Atlantic ports and to interior districts.

A complete field survey was made of plants producing concentrated acid for munitions purposes; a report was prepared on the possibility of using acid from fumes of western smelters; the possibility of increasing acid production at the zinc and copper smelters in the Eastern States was studied.

Reports were submitted to other Government establishments in connection with the construction of new acid plants and the allocation of raw materials. Largely because of the need of acid in making explosives the demand for acid during the war increased approximately two and one-half times.

The attention of the War Industries Board was called to the fact that if necessity should arise the supply of acid to the steel pickling industry could be curtailed 50 per cent through the substitution of niter cake, without producing hardships to that industry.

D. E. Fogg assisted in the work on sulphuric acid.

GRAPHITE.

Before the war most of the flake graphite used in the manufacture of crucibles for making brass and crucible steel came from Ceylon and Madagascar. In 1917 the domestic production of flake graphite of crucible grade was only about 3,400 tons, whereas the foreign imports were about 27,000 tons. It was felt that domestic production could easily be stimulated by creating a market for domestic flake and that the market could be created if the bureau's engineers demonstrated that satisfactory crucibles could be made with a larger percentage of domestic flake than had commonly been used.

FIELD INVESTIGATION OF COMMERCIAL PRACTICE.

A field investigation was made of commercial methods of sampling and analysis with a view to establishing more efficient relations between graphite producers and consumers, by recommending uniform specifications. The leading domestic producing areas were visited and a detailed report entitled "Preparation of Crucible Graphite" was published. On August 10, 1918, the War Industries Board requested that all crucible makers use 20 per cent domestic flake in their crucible mixtures for the balance of 1918 with an increase to 25 per cent in 1919. This action, which was taken on the recommendation of the Bureau of Mines, resulted in the establishment of a market for domestic flake graphite. This investigation was conducted by G. D. Dub.

EXPERIMENTS ON FINISHING GRAPHITE.

The Salt Lake City, Utah, experiment station of the bureau studied the processes of preparing commercial graphite. An improved method of finishing graphite, by which milling losses are greatly decreased, was devised. Under existing practice an unduly large proportion of the flakes was crushed to a size too small for crucible grade. Experiments were made with different devices and with different methods of finishing graphite, and the possibilities of each demonstrated. This work was under the direction of F. G. Moses, acting superintendent of the station.

EXPERIMENTS ON CRUCIBLE MANUFACTURE.

At the Columbus, Ohio, experiment station an extensive investigation of the possibilities of using larger proportions of domestic flake in the crucible mixtures was made and numerous tests were conducted. This study was given satisfactory results. This work was under the direction of E. A. Holbrook, then superintendent of the station.

COLLECTION OF GENERAL DATA.

At the Washington office, data were collected on methods of analyzing graphite and graphitic ores to determine the best practice, and on mill capacity of all plants in operation or under construction, their actual production, labor conditions, efficiency, and grades of graphite manufactured. H. S. Mudd conducted this work.

POTASH.

Because of the importance of potash in agriculture and explosives a review of the potash situation was made by A. W. Stockett. Although the normal annual consumption of potash in this country is probably 250,000 tons, with a domestic production in 1917 of only 32,000 tons, Mr. Stockett showed that the deficiency could be met by utilizing the Searles Lake deposit in southeastern California, the greensands deposits of New Jersey and adjoining States, and by erecting potash-recovery plants at cement works and at blast furnaces.

The bureau prepared for the War Department a report on the potash situation, and advised the Capital Issues Committee on applications for the construction of potash-recovery plants.

The Bureau of Mines, through its experiment stations, has done much experimental work on potash and has cooperated with manufacturers. The Berkeley experiment station cooperated with the California State Council of Defense in studying methods of stimulating production from saline deposits. An engineer of the bureau examined the salt lakes of Nebraska and the plants there. The Salt Lake City station conducted some experiments in the recovery of potash from leucite and other potash-bearing rocks.

LIMESTONE.

Soon after this country entered the war, owners of limestone quarries faced a serious shortage of labor caused by the drafting of men and the shifting of workers. There was danger that any considerable decrease in the output of fluxing limestone might ultimately result in a decreased production of pig iron. To meet this situation the Bureau of Mines issued and distributed to the limestone quarries a paper on "Labor Saving in Limestone Quarrying," prepared by Oliver Bowles, quarry technologist.

WHITE ARSENIC.

By the midsummer of 1917, it became evident that on account of the practically complete stoppage of arsenic imports, there would be considerable difficulty in obtaining from domestic sources enough white arsenic for insecticides, glass manufacture, sheep and cattle

dip, and other nonwar purposes; and the prospective shortage would be augmented by the probable manufacture of certain toxic gases for the War Department.

A survey of the situation was made in September, 1917, by A. E. Wells, who visited all of the arsenic plants in the United States and studied the possibilities of increasing production. An accumulation of dust in an old flue system of a smeltery at Great Falls, Mont., was disclosed, which yielded an unexpected supply of arsenic, large enough with the regular production of the other arsenic plants to supply the demand for nonwar purposes. In October, 1918, the War Department put in a heavy requirement, and steps were taken immediately to meet the demand. As it was believed that the war minerals act provided means for the Government to encourage directly an immediately increased production, Mr. Wells and H. S. Mudd examined several prospective sources of arsenic in the eastern States, and producers in the West were encouraged to plan expenditures to increase their output. However, at the signing of the armistice the War Department's requirements were cancelled, and all the new projects for increasing arsenic production were discontinued at once before extra expenditures were incurred, except a new plant at Anaconda, Mont. That plant is being built primarily for other purposes, the arsenic being merely a by-product.

PLATINUM.

Hennen Jennings, consulting engineer, and C. L. Parsons, chief chemist, of the Bureau of Mines, cooperated with the War Industries Board in the steps taken to reserve an adequate supply of platinum for war requirements. By act of Congress the Bureau of Mines was given authority to control the production and sale of platinum during the war. This work was conducted through the license and inspection system built up for administering the explosives regulation act.

TUNGSTEN.

Because of the value of tungsten in the manufacture of high-speed tool steels, needed in munition plants, the Bureau of Mines sought by advice and encouragement to aid the development of domestic deposits and thus increase imports and release foreign production to the allies. Early in 1918 the allied governments proposed to allocate the world's production for the year, estimated at about 24,000 tons, the United States to receive half, and the other half to go to England, France, and Italy. However, the United States requirements for 1918 were estimated at about 16,000 tons, and if the war had continued, nearly 18,000 tons for the year 1919.

At first the work on tungsten was in charge of J. H. Mackenzie, assisted by J. E. Maguire; J. S. Means made a field examination of

the principal tungsten districts in the United States. Later, H. C. Morris took charge of the work on the rare metals.

A series of special tungsten steels were prepared for tests by the Ordnance Department by H. W. Gillett, alloy chemist of the bureau, as related in another chapter of this bulletin. The tungsten for these experiments was prepared at the Golden station. Also at this station the conditions under which tungstic acid obtained in the treatment of tungsten ores may be efficiently reduced to metallic tungsten have been studied and the results published.

REPORTS ON POLITICAL AND COMMERCIAL CONTROL OF MINERAL RESOURCES.

In May, 1918, the Bureau of Mines, the United States Geological Survey, and other Government bureaus were invited to contribute to a series of reports on the political and commercial control of the mineral resources of the world initiated by Dr. J. E. Spurr, then a member of the Committee on Mineral Imports of the United States Shipping Board. J. E. Orchard, assistant mine economist of the Bureau of Mines, was placed in charge of the editing and publication of the reports, which are confidential and are being supplied to Government officials only. At present they are being used by the economic advisers of the American delegation at the peace conference. Steps are being taken by other departments of the Government to make similar studies of the other raw materials.

FIXATION OF NITROGEN AND OXIDATION OF AMMONIA.

The work of the Bureau of Mines in connection with the development of processes and plants for insuring an adequate supply of nitric acid and nitrates in this country ranks among its important achievements. This work, conducted in cooperation with the War Department, was the direct outgrowth of the necessity of rendering the Nation independent as regards a supply of nitric acid, essential in the manufacture of high explosives, and of the nitrogen compounds used in agriculture and other industries. Such a need was recognized in the national defense act of June 3, 1916, which (sec. 124) authorized the President to have made an investigation to determine the best, cheapest, and most available means of producing nitrates and nitrogenous materials used in munitions and in the manufacture of fertilizers and other products, and to have erected such plants as might be deemed necessary.

About two months previous to the passage of this act, the Secretary of the Interior had, April 7, 1916, offered the Secretary of War the aid of the Interior Department in any capacity that would be useful for national preparedness, and called attention to the fact that the Bureau of Mines could aid in the study of methods and materials necessary for the large-scale manufacture of nitrogen products.

During April and May, 1916, C. L. Parsons, chief chemist and chief of the division of mineral technology of the Bureau of Mines, had several informal conferences with Brig. Gen. William Crozier, Chief of Ordnance, in regard to nitrate supply, and at Gen. Crozier's request Dr. Parsons made a tentative report on June 6, 1916, on the outlook for the fixation of atmospheric nitrogen by existing methods.

On June 9 the Secretary of War inquired whether the Bureau of Mines was in position to undertake such researches as would demonstrate the practicability of oxidizing ammonia to nitric acid, and asked for an estimate of the funds that would be needed to carry on this work, in view of the appropriations that had been made to the War Department under section 124 of the act approved June 3, 1916. The Secretary of the Interior replied on July 13 that the Bureau of Mines would be glad to undertake this work and outlined a tentative plan for procedure.

On August 1 the Secretary of War proposed that qualified representatives be sent abroad to study the methods of manufacturing nitric acid, otherwise than from sodium nitrate, followed in the various

countries of Europe. On August 3 the Secretary of the Interior informed the Secretary of War that arrangements were in progress, after consultation with the Chief of Ordnance, for a cooperative agreement between the Bureau of Mines and the Semet Solvay Co. for demonstrating on a plant scale the possibility of oxidizing ammonia produced from by-product coke ovens, and that preliminary investigations had already begun. Secretary Lane suggested that the War Department set aside funds to assist in this work and also to pay the expenses abroad of the investigators proposed by the Secretary of War in his letter of August 1. Secretary Lane also said that he had designated Dr. C. L. Parsons, chief chemist of the Bureau of Mines, to make this report as the representative of the Interior Department, and suggested that Mr. Eysten Berg, an engineer long familiar with the nitrogen fixation processes used in Norway, might be associated with him in making the investigation. On August 14 the Secretary of War accepted the suggested arrangement and allotted \$10,000 and outlined a method of procedure for the expenditure of this sum.

A contract with the Semet Solvay Co. was signed August 10, 1916, whereby the Semet Solvay Co., in cooperation with the Bureau of Mines and with the approval of Gen. Crozier, undertook to erect in Syracuse a plant, from plans furnished by the Bureau of Mines, for the chief purpose of demonstrating whether ammonia could be successfully oxidized on a commercial scale to nitric acid, and especially whether ammonia produced by the destructive distillation of coal was as suitable for the purpose as cyanamid.

Early in 1916 the American Cyanamid Co. had carried on experiments on the oxidation of ammonia at its plant at Niagara Falls, Ontario, and during the summer of 1916 had erected at Warner's, N. J., a small plant having a capacity of approximately 1 ton of nitric acid a day, for producing the acid from cyanamid ammonia by the catalytic action of electrically heated platinum. During the summer of 1916 Dr. Parsons was allowed to visit this plant, with the distinct understanding that although certain details of the process would not be revealed to him, nevertheless he was at liberty to use anything that he himself saw during his visit.

Dr. G. B. Taylor and J. H. Capps, of the Bureau of Mines, began laboratory studies of oxidation methods in the Pittsburgh experiment station of the bureau and J. D. Davis began similar studies with chemists of the Semet Solvay Co. at Syracuse, N. Y. The Bureau of Soils, Department of Agriculture, also sent a representative to the laboratories of the Semet Solvay Co., but he remained only a short time. Mr. Davis had associated with him in his early experimental work Bryan Handy, of the Semet Solvay Co., who received advice

from Dr. L. C. Jones, chief chemist of the company, and G. N. Terziev, who had previously worked on the oxidation of ammonia by the use of nonmetallic catalytic agents. C. D. Davis, of the Pittsburgh station, was assigned to assist J. D. Davis in this work.

Before he left for Europe early in October, 1916, Dr. Parsons, assisted by others, prepared general plans for the erection of a small plant at Split Rock near Syracuse. The plant was to be much like the plant at Warner's, N. J., platinum gauze being used as a catalyzer. When Dr. Parsons returned from Europe in December, 1916, this plant was nearing completion. The chemists mentioned above made many experiments with the hope of utilizing nonmetallic catalyzers. Many such catalyzers were found that worked successfully for a short period, but nothing to compare with platinum was ever discovered. Hence this line of experiment was abandoned, only apparatus in which platinum was the basic agent for the conversion of ammonia to nitric acid was tried.

Dr. Parsons was transferred to the War Department for the last three months of the year 1916. As chemical engineer to the Ordnance Department he visited, with Mr. Eysten Berg, the plants in France and Italy, and later alone visited the plants in England, Norway, and Sweden that were working on the fixation of atmospheric nitrogen. He returned to the United States on December 24, 1916; made his preliminary report to the Ordnance Department on January 17, 1917; and gave his final conclusions on April 30, 1917.

Meanwhile, a committee of the National Academy, appointed at the request of the Secretary of War, had reported its findings to the Ordnance Department. The members of this committee were Dr. A. A. Noyes, chairman, Dr. L. H. Baekeland, Dr. Gano Dunn, Dr. Charles Herty, Dr. W. K. Lewis, Mr. M. I. Pupin, Prof. T. W. Richards, Mr. Elihu Thompson, and Prof. W. R. Whitney. In order to harmonize the reports made by the committee and by Dr. Parsons, the Secretary of War appointed a committee on nitrate supply consisting of Brig. Gen. William Crozier, Admiral Ralph Earle, Brig. Gen. William M. Black, Frederick Brown (Bureau of Soils), Dr. L. H. Baekeland, Dr. Gano Dunn, Dr. Charles Herty, Dr. W. F. Hillebrand (Bureau of Standards), Dr. A. A. Noyes, Dr. W. R. Whitney, and Dr. C. L. Parsons (Bureau of Mines). This committee met on May 11, 1917, and made its final report to the Secretary of War. It adopted practically all of the recommendations made in the reports of the chief chemist of the Bureau of Mines. These reports, with the exception of the report of the committee of the National Academy, were printed in the *Journal of Industrial and Engineering Chemistry*, September, 1917, and in a pamphlet issued by the Ordnance Department, entitled "A Statement of Action Taken and Contemplated Looking to the Fixation of Nitrogen."

The work of constructing and operating the plants for the fixation of nitrogen was turned over to a special division of the Army known as the nitrate division, Ordnance Department, under Col. J. W. Joyes. Work on the oxidation of ammonia continued for some time at Syracuse, and the nitrate division also established a small experimental laboratory of its own at Sheffield, Ala., for studying the oxidation of ammonia.

Early in 1917 G. A. Perley, of New Hampshire College, was assigned to the ammonia oxidation work at Syracuse as a member of the Bureau of Mines. Shortly after he was commissioned a first lieutenant in the Ordnance and later promoted to captain. He proved an able associate of J. D. Davis and the other chemists there in developing the ammonia oxidation process.

It was early determined that the German apparatus, as modified by W. L. Landis, of the American Cyanamid Co., would readily oxidize ammonia from by-product coke plants with high efficiency, but so much electricity was needed to maintain the heat of the single sheet of platinum gauze used that a method using no external heat was plainly desirable, especially as there was a large amount of waste heat from the reaction. The first modification of the apparatus was to use three or four layers of platinum gauze in the hope of reducing the proportion of heat radiated. This hope was realized and apparatus of essentially the same shape as that previously used, but having multiple gauze, worked fairly well and gave fairly high efficiencies.

Dr. Parsons had already given the experimenters data on apparatus used in England and France. Additional information on the multiple-gauze apparatus was now sent to the European representatives of the Semet Solvay Co. and became the basis of experimental plants that were constructed in England except the large plant erected at Dagenham Docks, which used the Ostwald process developed at Vilvorde, Belgium, before the war.

Although the experiments with the multiple-gauze apparatus gave fairly good results, they were not entirely satisfactory, as the temperature of the gauze was not maintained at the point most desirable for high efficiencies. After considerable thought, an apparatus was developed and patented by Dr. Jones, of the Semet Solvay Co., and Dr. Parsons. In this apparatus the layers of platinum gauze were arranged within a cylinder made of refractory material. The layers of gauze radiated to each other and also raised the walls of the refractory cylinder to a red heat so that it in turn helped to maintain a high temperature. With pure ammonia this apparatus proved a complete success; one single apparatus was in continual use day and night for six months at the plant of the Semet Solvay Co. and gave

an average efficiency of more than 90 per cent. This form of apparatus was adopted for Chemical Plant No. 1 at Sheffield, Ala.

Another important development of this work was the determining of the impurities that are liable to be present in ammonia and must be removed to insure oxidation with high efficiency. These impurities are chiefly iron in any form, oil or similar organic material carried mechanically, and phosphine. The last has a very poisonous action, but it is present only in cyanamid ammonia and can be readily removed.

DEVELOPMENT OF PLANT BUILT FOR PRODUCING SODIUM CYANIDE BY THE BUCHER PROCESS.

Reports from France received by the Bureau of Mines indicated strongly that hydrocyanic acid was desirable for gas warfare. The French were preparing to use it in shells and were trying to purchase cyanide in America.

On September 7, 1917, the Secretary of the Interior wrote to the Secretary of War calling attention to the Bucher process of the Nitrogen Products Co., and offering the services of the Bureau of Mines in constructing and operating a plant for making sodium cyanide. This letter was acknowledged by the War Department on September 24, with the statement that the matter was being investigated. On November 26 a letter from the Assistant Secretary of War definitely accepted the offer of the Bureau of Mines to undertake the work. On December 5 the Director of the Bureau of Mines asked the Chief of Ordnance to allot the necessary funds, and said that Dr. C. L. Parsons, chief chemist of the Bureau of Mines, had been designated to take charge of the engineering, building, construction, and operation of the plant.

In the meantime Capt. E. J. W. Ragsdale, of the Ordnance Department, had been making preliminary arrangements, through conferences with the officials of the Nitrogen Products Co. C. W. Marsh was appointed consulting engineer. Dr. Norman E. Holt, formerly of the Nitrogen Products Co., and thoroughly familiar with the experimental development of its process, was commissioned a captain in the Ordnance Department. R. M. Ross was appointed assistant engineer, and was commissioned a first lieutenant in the Ordnance Department some months later. Plans for the plant were prepared as rapidly as possible after the funds were made available. The early plans were for a 15-ton plant. As later advices from France, transmitted to Capt. Ragsdale on December 14, indicated that the probable use of cyanide would be less than previously anticipated, the plans were changed to a 5-ton basis.

On December 27, 1917, the Chief of Ordnance set aside \$750,000 to cover the cost of a 5-ton plant. This fund was retained by the Ordnance Department, but was subject to vouchers duly approved by the Bureau of Mines.

On January 8, 1918, a communication received from the Director of the Research Division of the Gas Warfare Service stated that a committee consisting of Dr. J. F. Norris, Dr. John Johnston, Col. William McPherson, and Col. William Walker, which had considered the need for cyanide, believed that a 5-ton plant was not large enough and recommended the building of a 10-ton plant. Because of this recommendation the Ordnance Department was asked for more funds on an estimate that the 10-ton project would cost approximately \$2,000,000, as cantonments and other requisites for an enlisted personnel of 350 men and 25 officers would have to be provided at the site chosen.

CONSTRUCTION.

The preliminary engineering work proceeded rapidly and was nearly completed by the time contracts were signed, February 28. In the meantime, at the recommendation of the Council of National Defense, it had been deemed wise to ask the Cantonment Division of the Army to assign officers who would take charge of actual construction work, and to designate a contractor. Of the funds placed to the credit of the Bureau of Mines and the Ordnance Department \$500,000 were accordingly transferred to the construction division of the Quartermaster General's Office. Maj. R. A. Widdicombe was chosen as construction quartermaster and Maj. J. R. Werth as supervising constructing quartermaster. Frazer, Brace & Co. were designated contractors.

Work at the site begun March 1 and construction proceeded rapidly, the only delays being those from inability to obtain structural steel in the months of May and June. The construction work carefully followed the plans of the engineering staff employed by the bureau and was subject to the direction and approval of Dr. C. L. Parsons, in charge of the work.

In order that the plant might be ready at the date indicated, a corps of officers and men were trained in a small experimental plant of the Nitrogen Products Co. at Saltville, Va. Capt. C. O. Brown, chemical engineer of the Ordnance Department, was chosen commanding officer in charge of plant operations. He was assisted by Capt. N. E. Holt, who proved invaluable both in planning the plant construction and in seeing that the process worked smoothly. Conferences were held from time to time with the engineers and officers of the Ordnance Department as the work progressed.

Outside of the cantonment buildings, roads, filtering plant, electric installations, sewers, fire protection, and other subsidiary details, the main plant itself had three essential divisions housed in three main buildings, known as the mechanical, retort, and lixiviator buildings.

The mechanical building, for the preparation of the raw material and its formation into special briquets, was designed largely by Capt. Holt and C. W. Marsh, assisted by Lieut. R. M. Ross. The retort building was designed chiefly by Mr. Marsh, assisted by Capt. Holt, Lieut. Ross, and others. The furnaces in the retort building were designed by special furnace engineers under Mr. Alfred Ernst with the assistance of Messrs. E. A. W. Jefferies and J. W. Loomis. The plans for the producer-gas equipment, flues, etc., for these furnaces were furnished by the Morgan Construction Co. The planning and engineering of the lixiviator building was done by Capt. Holt, assisted by J. W. Emig of the York Manufacturing Co., and other engineers of that company which supplied the apparatus.

The original intent was to obtain the nitrogen from the waste gases of the carbonating towers of the plant of the Mathieson Alkali Co., at Saltville, and the original contract provided for the nitrogen being furnished by that company. It early became evident, however, that the cost of a plant for producing this nitrogen would be excessive and that there was no definite assurance that nitrogen could be procured regularly. Accordingly, the plans for the production of pure nitrogen were radically changed and arrangements were made with the Air Reduction Co. of New York for erecting three Claude towers. These towers were built and installed.

The land within the plant survey comprised some 35 acres rented from the Mathieson Alkali Co. with the privilege of purchase. The plant required some 40 buildings of which 25 were for the men and officers and 15 for the plant proper. When the construction division finally turned the plant over as ready for operation on November 4, 1918, Maj. C. O. Brown was in local command, reporting to Dr. Parsons. Under him were 17 officers besides the enlisted men.

PLANT PUT IN OPERATION.

The few units that had been previously turned over to the operating department functioned well. The plant was running successfully, though not on full scale, when the armistice was signed on November 11. Orders were immediately issued by the Chief of Ordnance to slow down work, and thereafter for a few weeks one bank of furnaces was run to obtain data. A few changes in burner design and furnace construction were necessary, but these were minor and easily made.

There is no question whatever that the plant will produce sodium cyanide to the full capacity for which it was planned. On November 11 the plant was 190 men short in its personnel for full operation.

The total funds allotted for the plant amounted to \$2,800,000 and approximately \$2,500,000 was spent in construction and early operation.

PLANT TURNED OVER TO ORDNANCE DEPARTMENT.

On November 26, the Secretary of the Interior informed the Secretary of War that the plant had been tried out and was working properly, and that he was ready to turn it over to the Ordnance Department for operation. The Secretary of War then assigned the future control of the plant to the nitrate division and on December 21, 1918, the control of the plant and its personnel passed from the Bureau of Mines to the Ordnance Department.

In considering the success achieved one should remember that the Bucher process was new and had never been tried on an extensive manufacturing scale, although the experimental plant erected at Saltville gave much data for the construction of the larger plant. The plant as constructed will produce cyanide at a price much lower than it could have been purchased in the open market.

Special credit for the engineering is due to Capt. N. E. Holt, Mr. C. W. Marsh, and Lieut. R. M. Ross, and Maj. C. O. Brown. Credit for the plant construction is due Maj. R. A. Widdicombe of the construction quartermaster's office and his assistants, and Maj. J. R. Werth, supervising constructing quartermaster. Many important details of the early plant operations were worked out by other officers assigned to the work in Saltville. Every officer carried out faithfully and well the work assigned to him.

Dr. Parsons requests that special mention be made of the excellent work of Lieut. B. V. Reeves in charge of the retort building, Lieut. W. M. Bowman in charge of the lixiviator building; and Lieut. F. A. Vestal in charge of the mechanical preparation building. Capt. E. J. Mullen, detachment commander, a chemical engineer of experience who was especially detailed for the procurement and selection of the personnel, handled plant operations with ability. Maj. C. O. Brown, from the time he was appointed commanding officer and assigned to the Bureau of Mines, displayed intelligence and good judgment in all his work. The ability he showed in handling the plant and its personnel merits the highest commendation.

